SOLECTRIA
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Designed-in Reliability

Matt Ursino
Sr. Reliability Engineer
matt.ursino@solectria.com

MADE IN USA

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Yaskawa Quality

is more than a measurement. Its an Experience

By any Measurement, the Quality of Yaskawa Products is Second to None

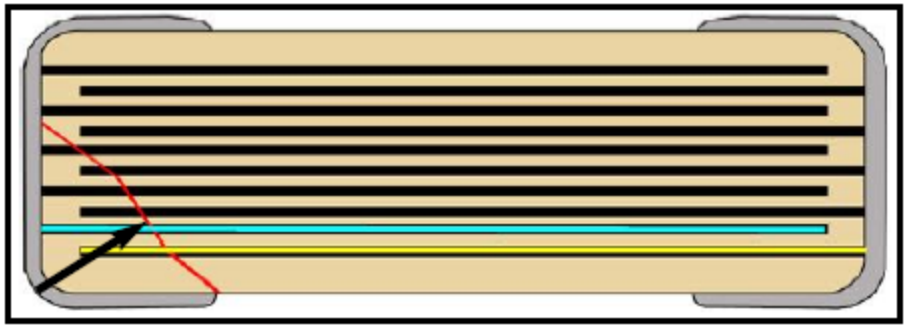
We're the only industrial drives and motion control manufacturer to win the Deming prize – the most prestigious quality award in manufacturing.

Designed-in Reliability

How do we “design-in” reliability?

1) **Careful selection of components**
2) **Derating components to increase design margins**
3) **Stress Testing (HALT, ALT, HASS, etc.)**

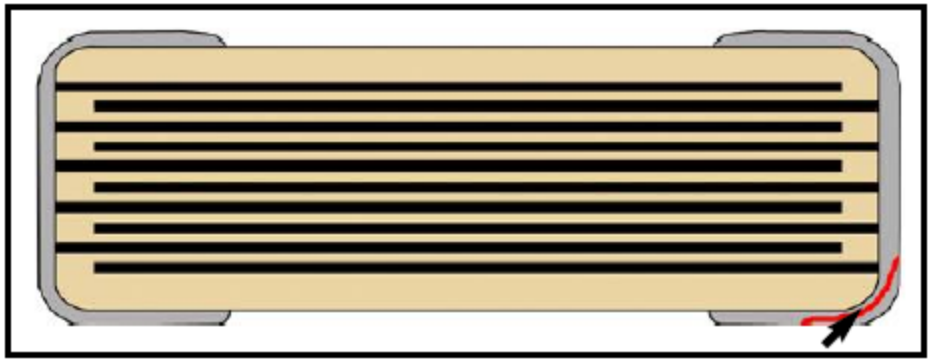
Careful component selection:



Ceramic Capacitors - Flex cracks

Yellow electrode represents (+); blue electrode represents (-); flex crack leads to short circuit.

Flexible termination



Flexible termination moves flex cracks to the end termination, away from the ceramic body.

Film Capacitors vs. Electrolytic

Identical cap bank composed of 600V capacitors

Electrolytic Capacitors	MTBF = 2.7 million hrs	Useful Life 10-15 yrs
Film Capacitor	MTBF 2.6 million hrs	Useful Life 20-30 yrs

MTBF calculation via Telcordia Standard

Electrolytic Caps have dry-out failures in 10-15 years

Derating of components

Basically running a component well below their max ratings:

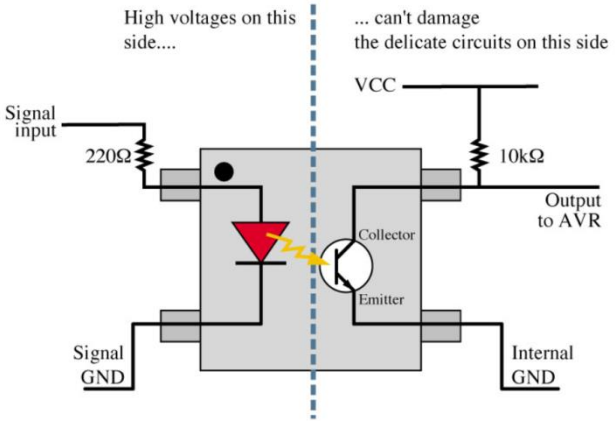
For example Operating an 800V Film capacitor at 600V

or

For example Operating a resistor at 50% of it's max rated power

Opto-couplers

Ambient Temps



Used in many critical GFDI circuits as well as other voltage isolation circuits.

25C MTBF = 129 million hrs (FIT 7.75)

60C MTBF = 5.38 million hrs (FIT 186)

That's 24 times reduction in MTBF 60C vs. 25C!!!

MTBF calculation via Telcordia Standard

Types of Stress testing:

What is HALT (Highly Accelerated Life Testing)?

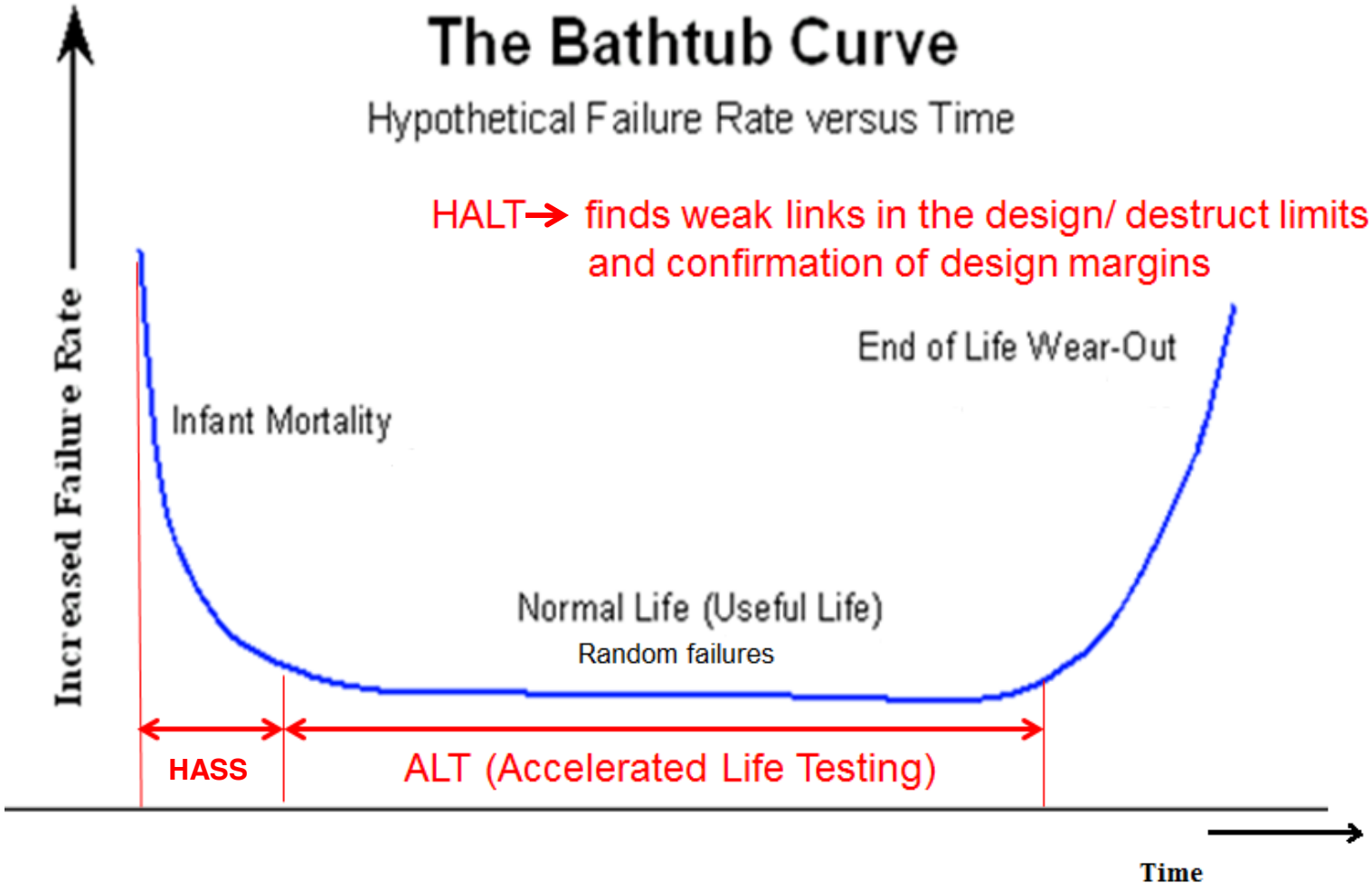
HALT is a stress testing method used to determine the operating and destruct limits of a design - why those limitations exist and what is required to increase those margins. HALT, therefore, stresses products beyond their design specifications and looks for weak links in the design.

What is ALT (Accelerated Life Testing)?

ALT is the process of *testing* a product by subjecting it to conditions (temperatures, voltage, vibration rate, pressure etc.) in excess of its normal service parameters in an effort to uncover potential modes of early wear-out/failure in a relatively short amount of time.

And what about HASS (Highly Accelerated Stress Screen)?

HASS testing is an accelerated reliability screen that can be done in production and can reveal latent flaws not detected by ESS, burn-in and other test methods. HASS testing uses stresses beyond specification, but within the capability of the design as determined by the HALT.



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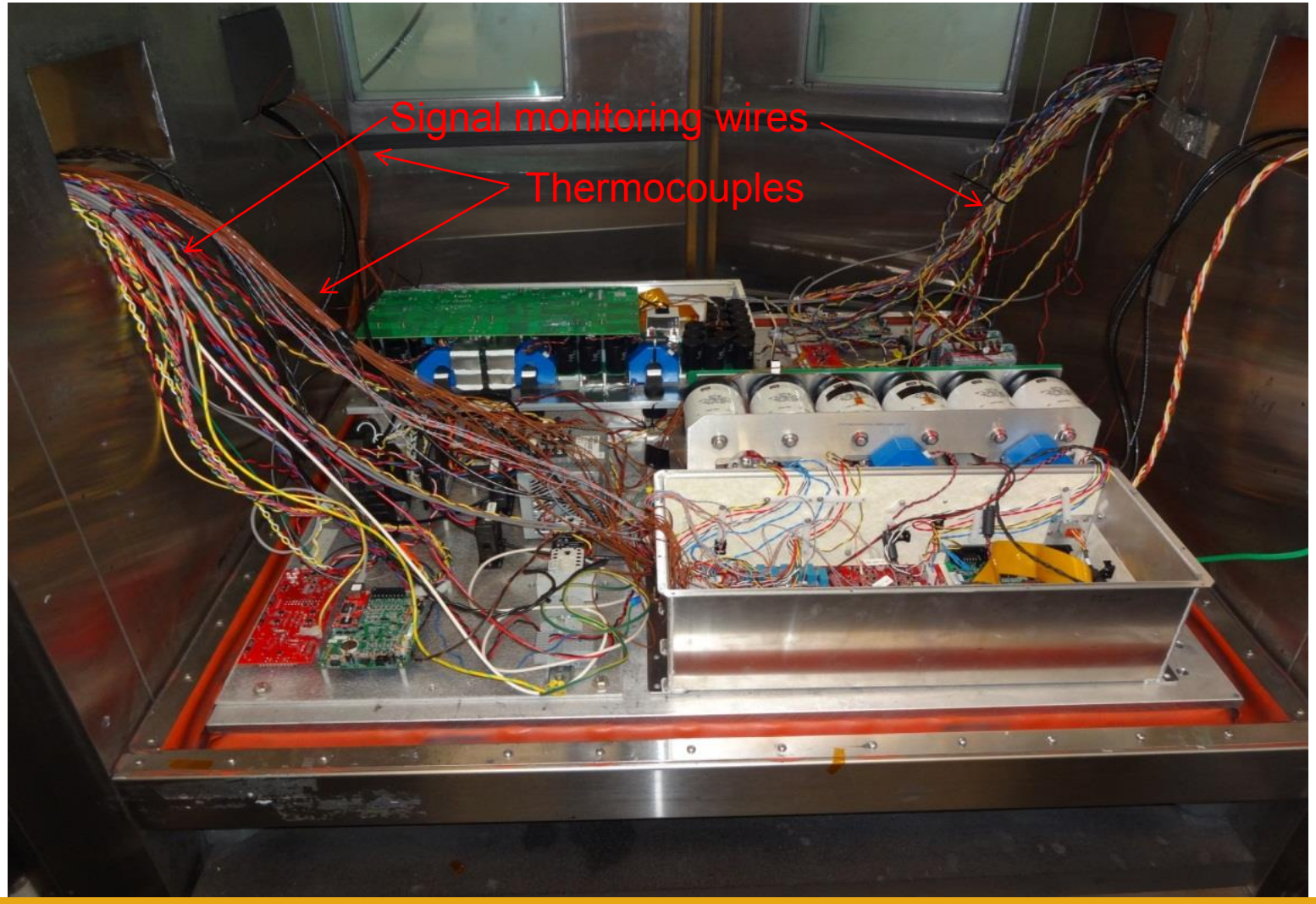
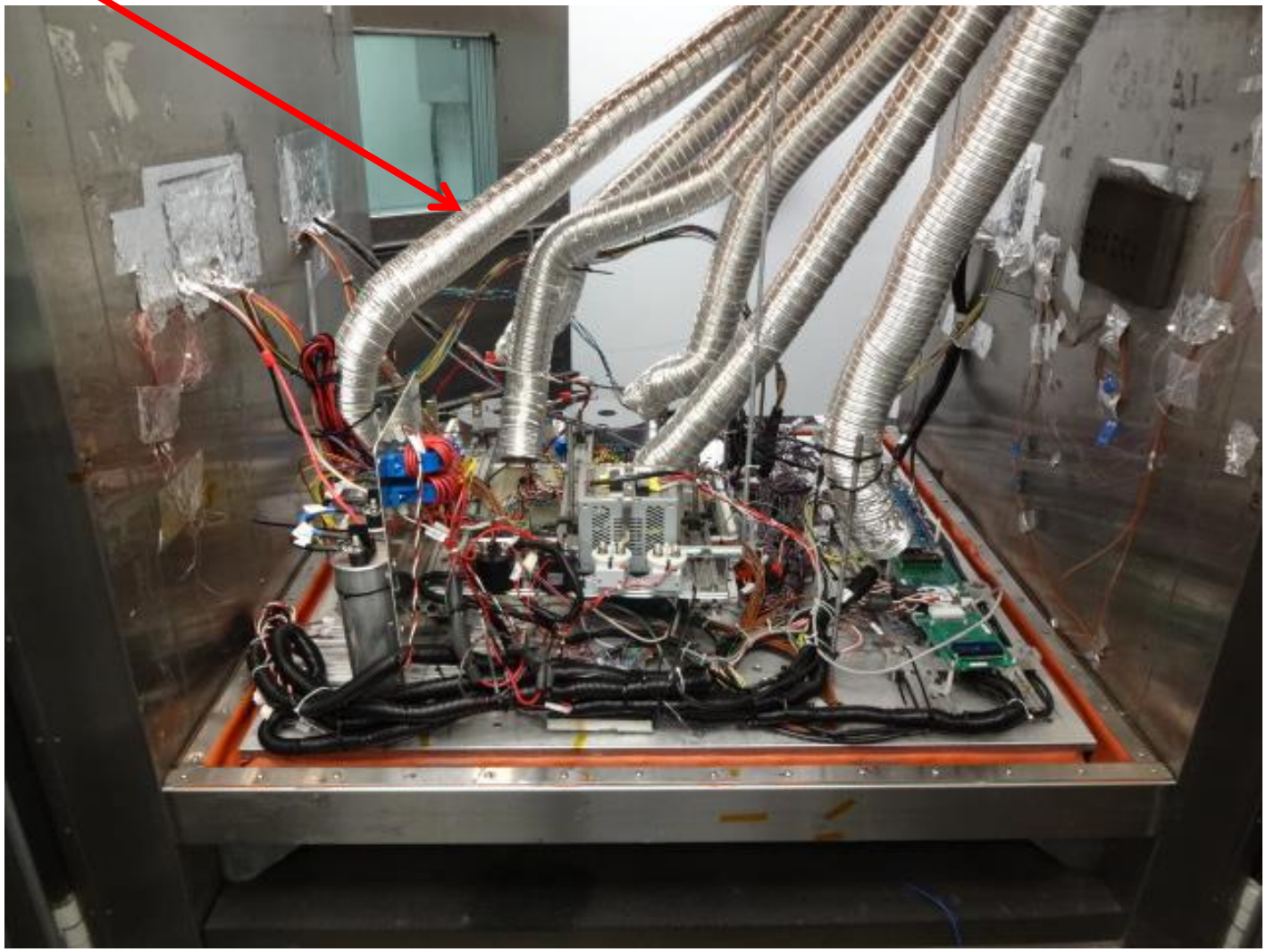
HALT Testing at Solectria

Typical HALT set up



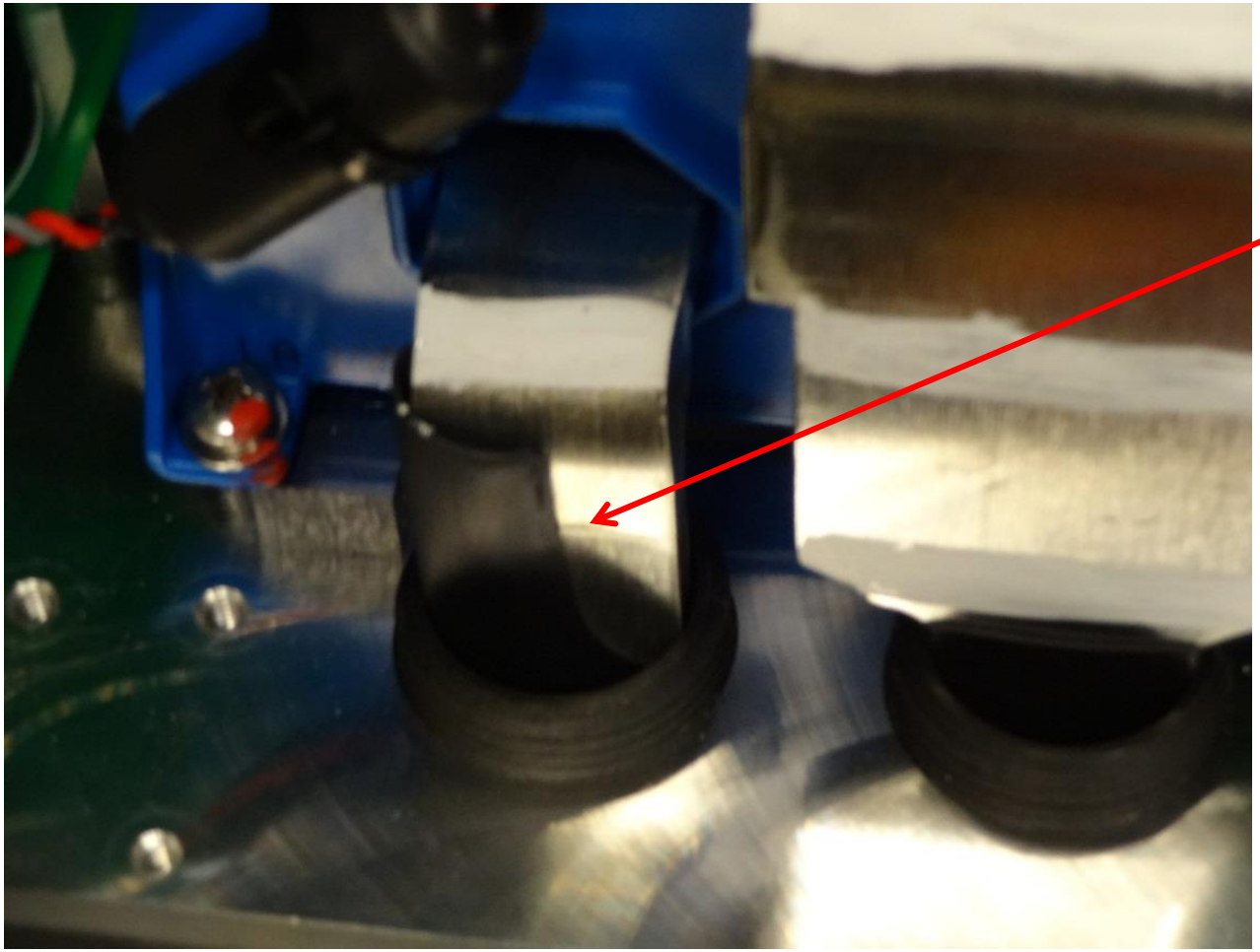
Cold and Heat being guided to critical circuits via air ducts



Phase 1 Thermal Step Stress

- 10C steps, 15 minute dwells
- 2minutes before end of dwell we induced a GFDI fault

Example of finding during thermal step stress



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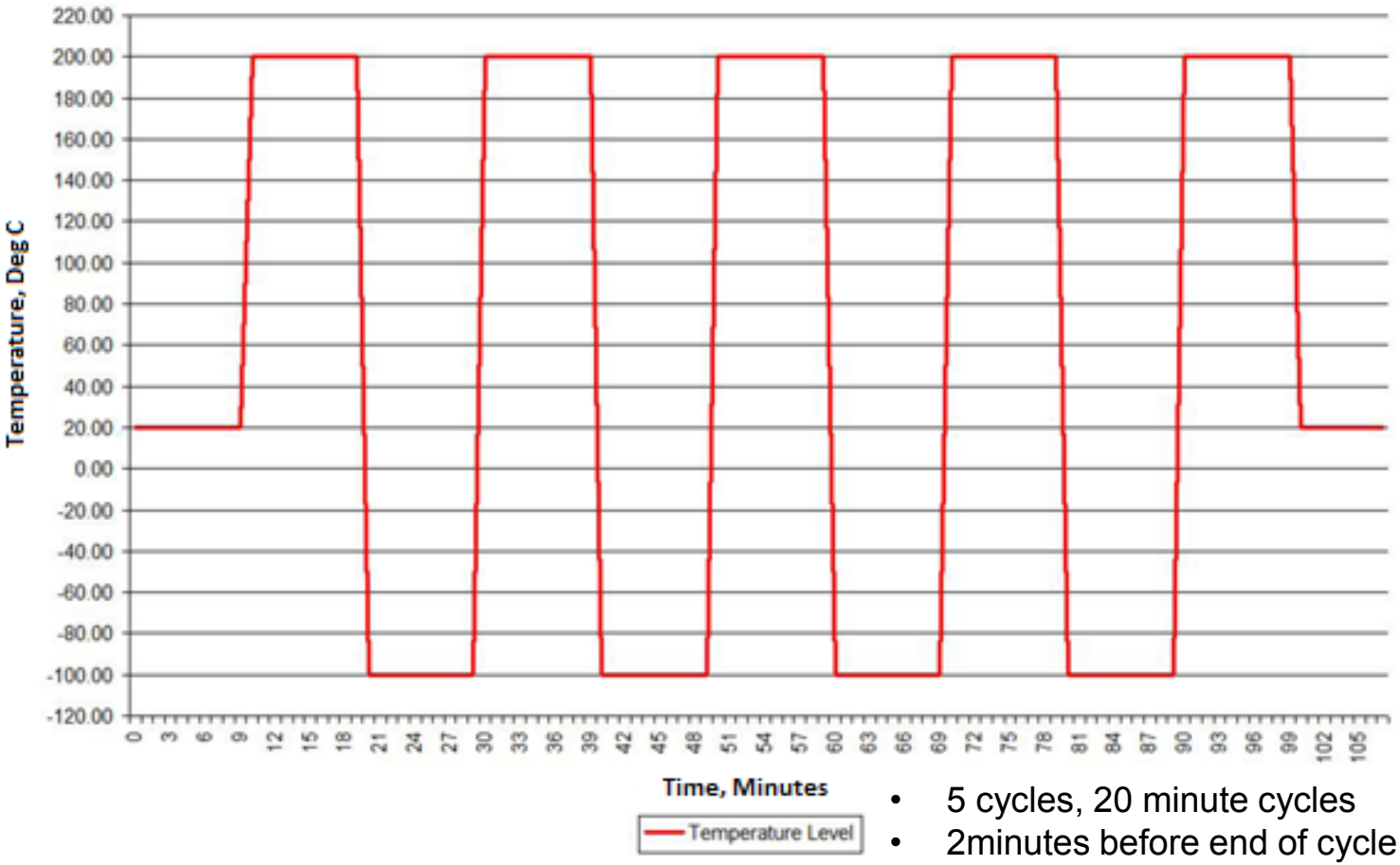
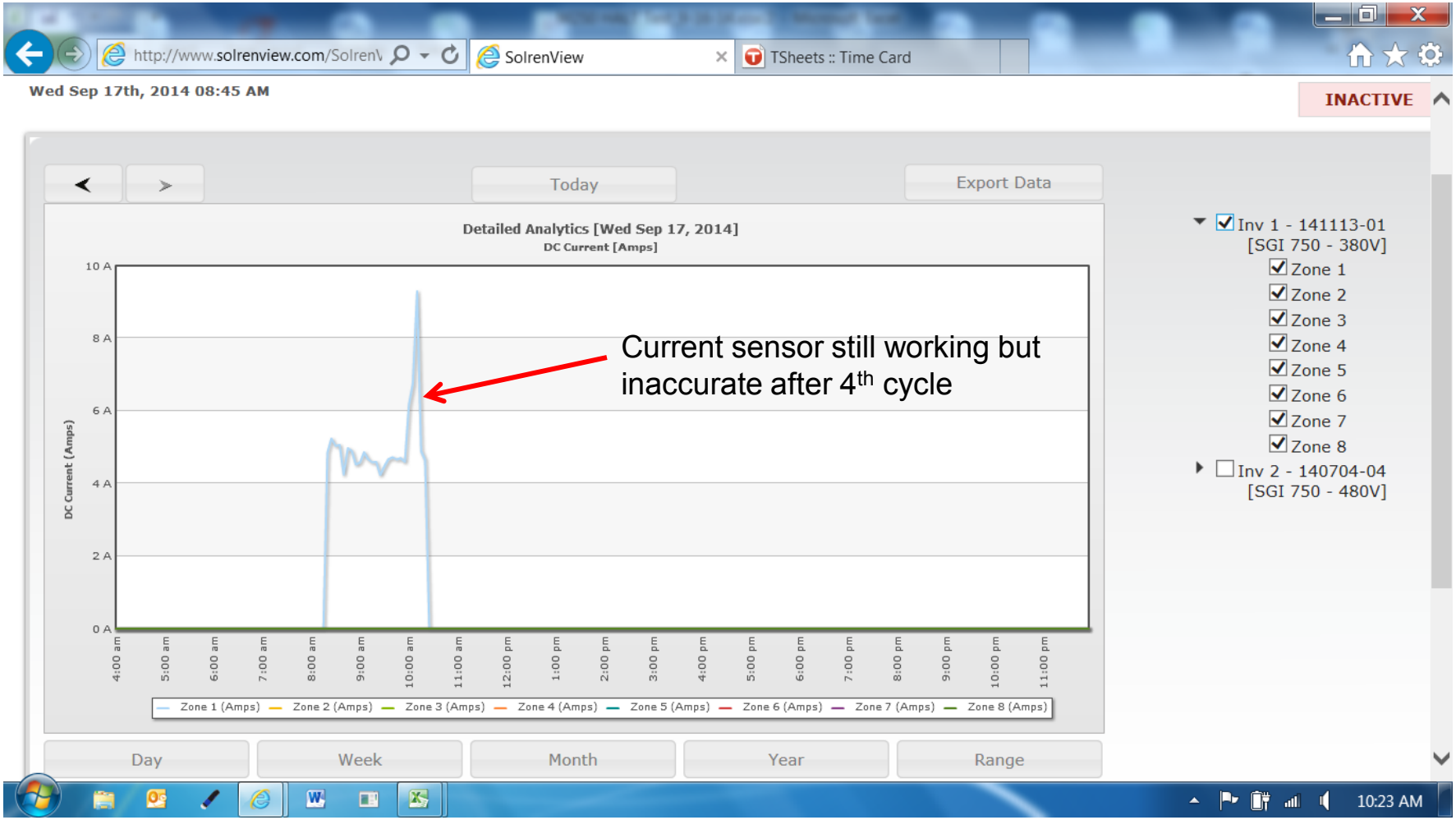
Phase 2 Rapid Thermal Stress

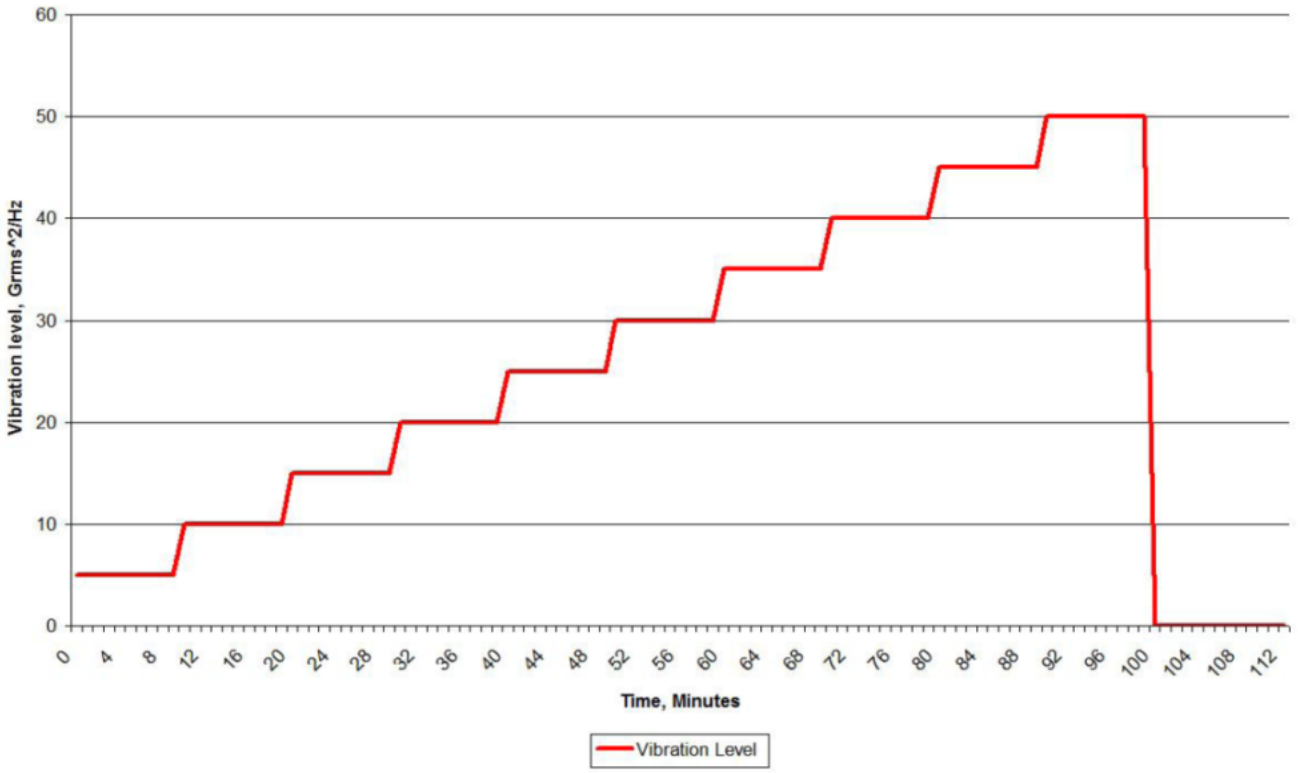


- 5 cycles, 20 minute cycles
- 2minutes before end of cycle we induced a GFDI fault

Example of findings during thermal cycle stress

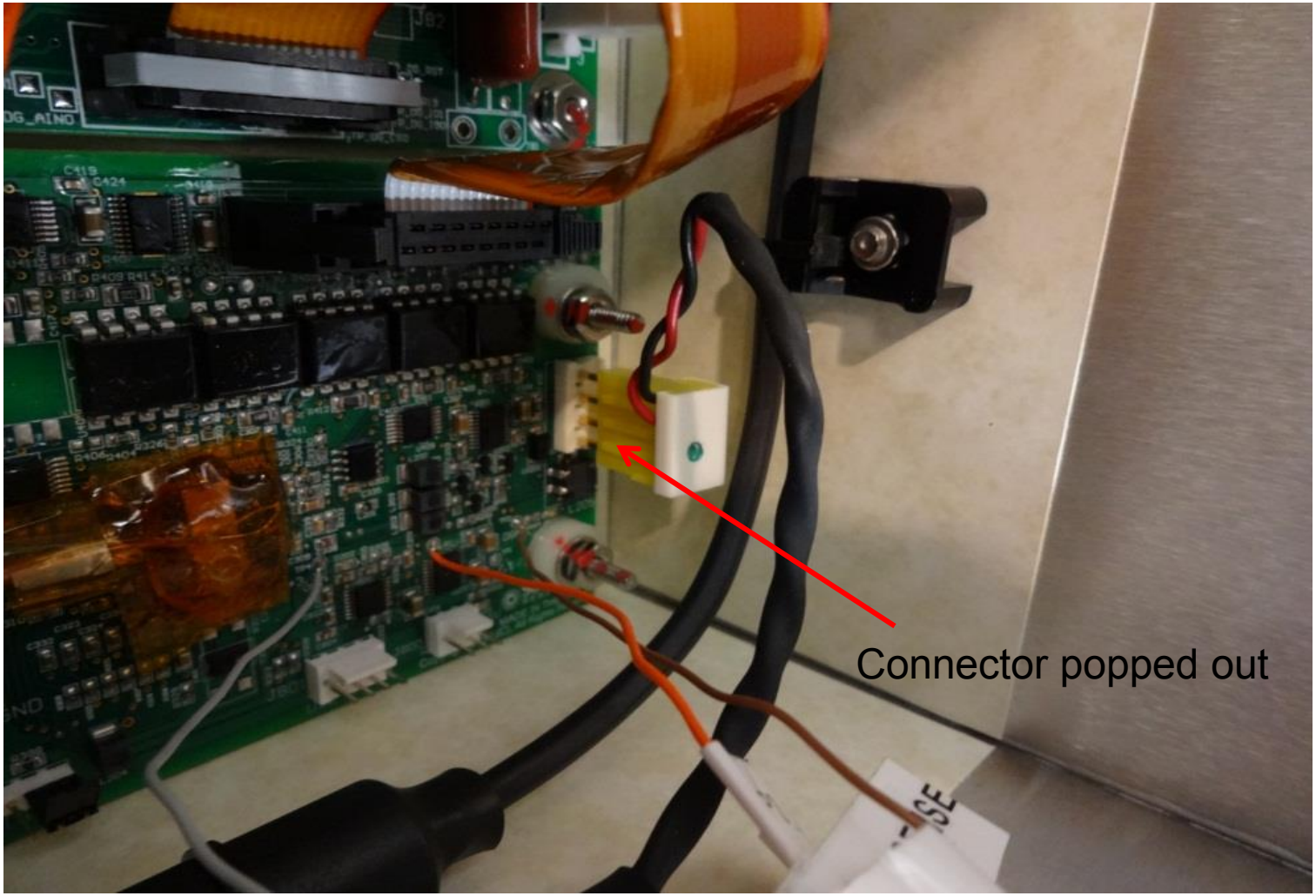


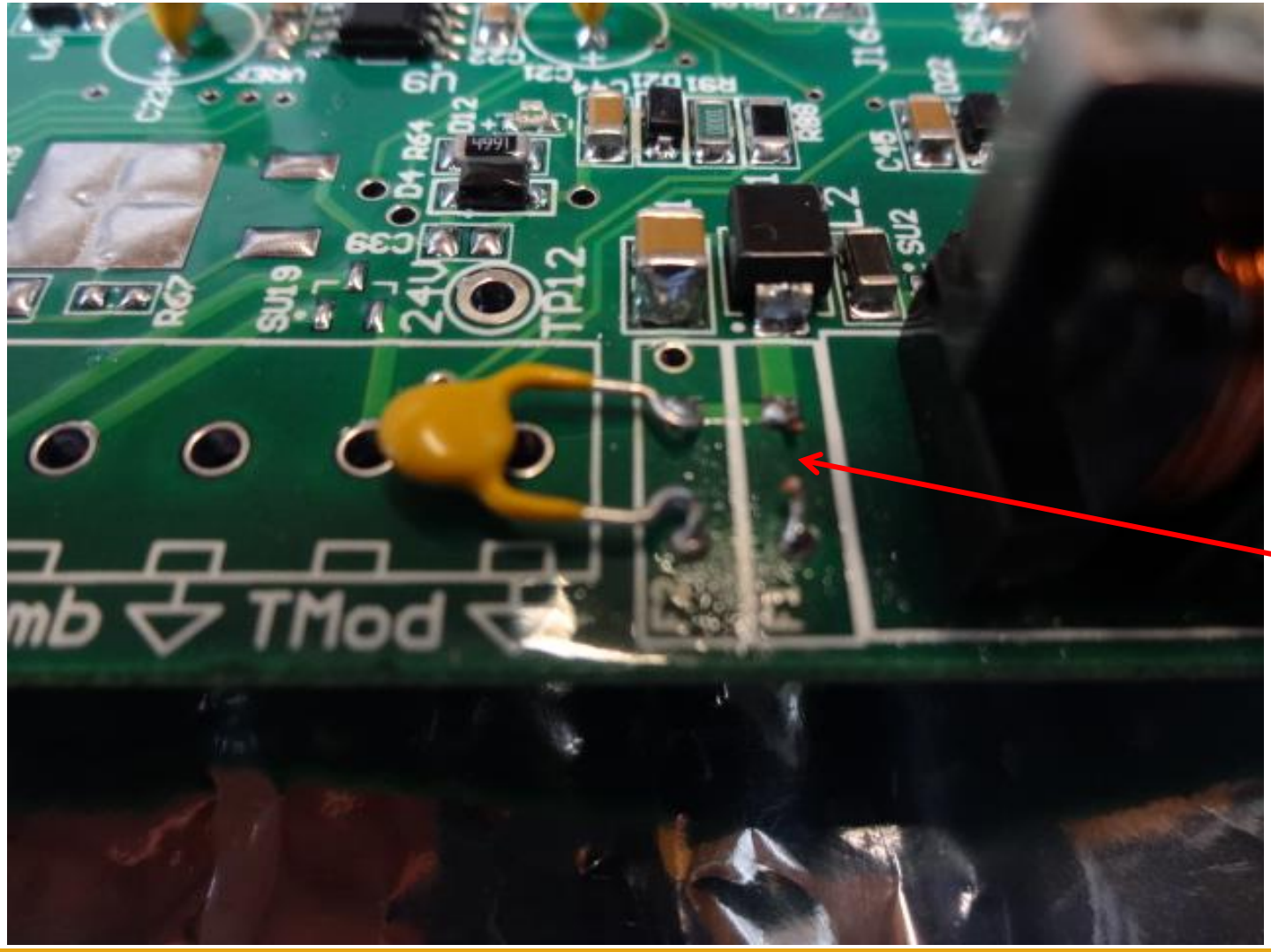
Phase 3 Vibration Step Stress



- 0gRMS to 60gRMS in 5gRMS increments
- 10 minutes dwells
- Starting at 30gRMS, 9 minute dwells + 1 minute at 5gRMS
- 2 minutes before end of dwell we induced a GFDI fault

Examples of findings during vibration stress





Component sheared off
(need to add RTV)

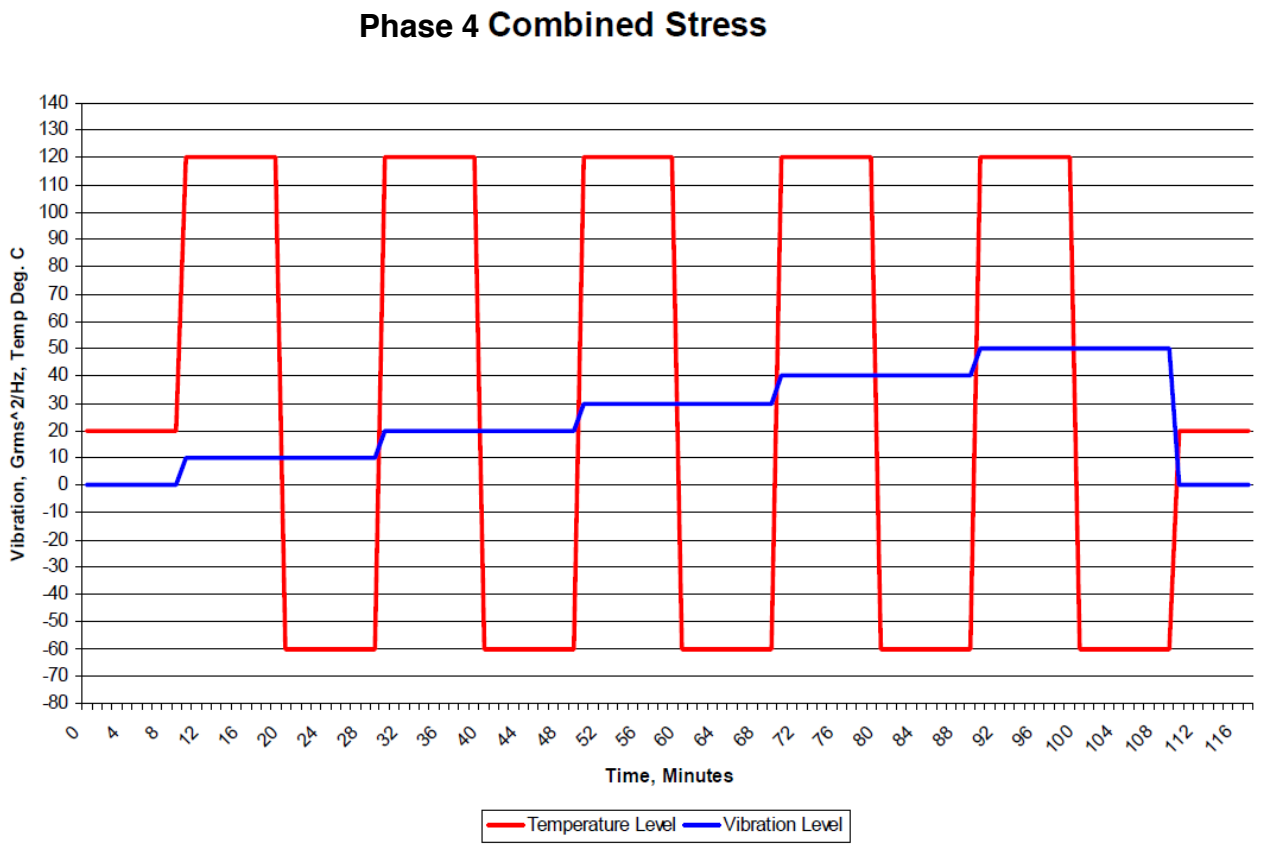


Figure 7: Sample Combined Stress Test Graph

Examples of findings during Combined stress test

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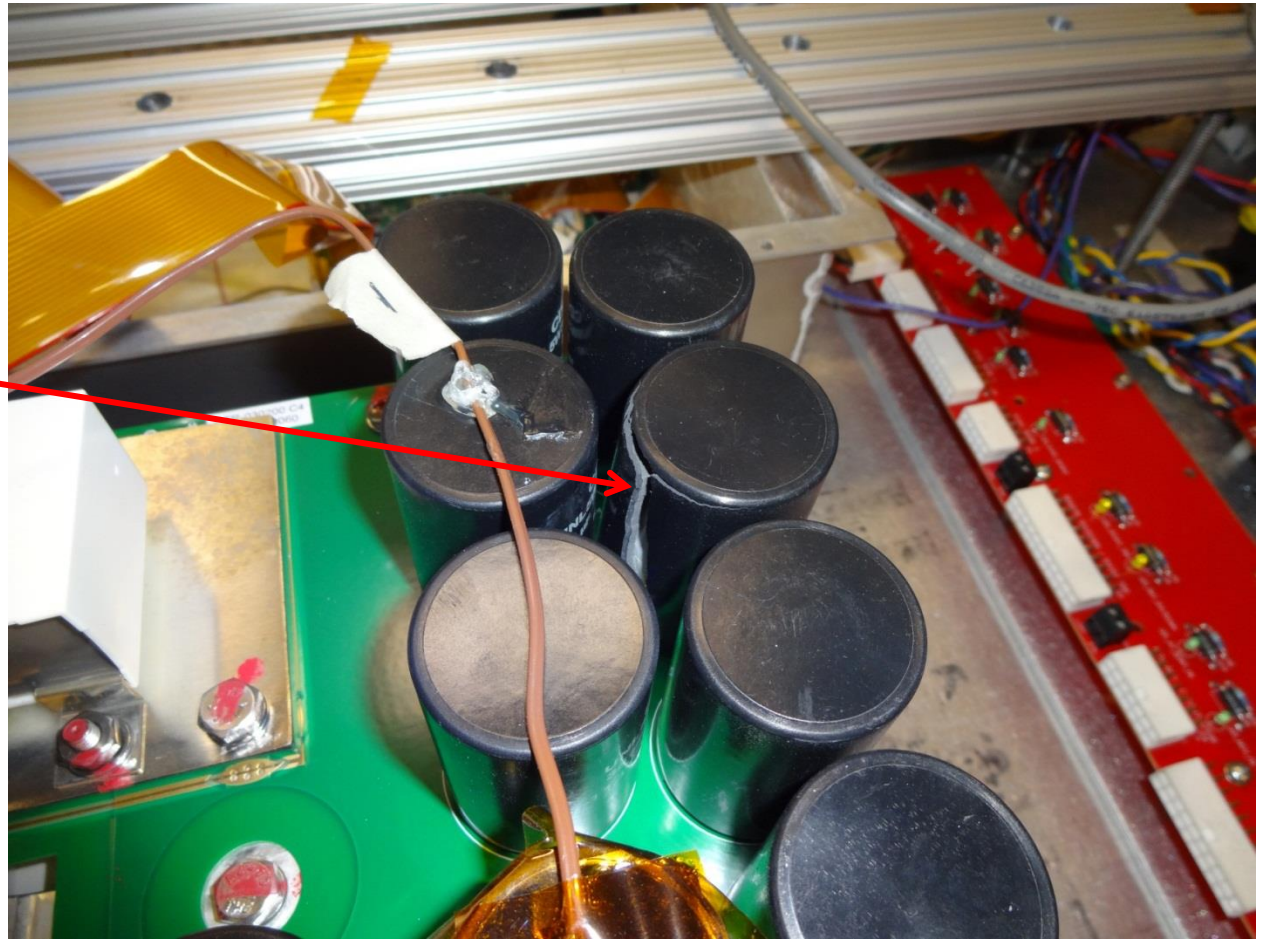
Cracked high voltage capacitor



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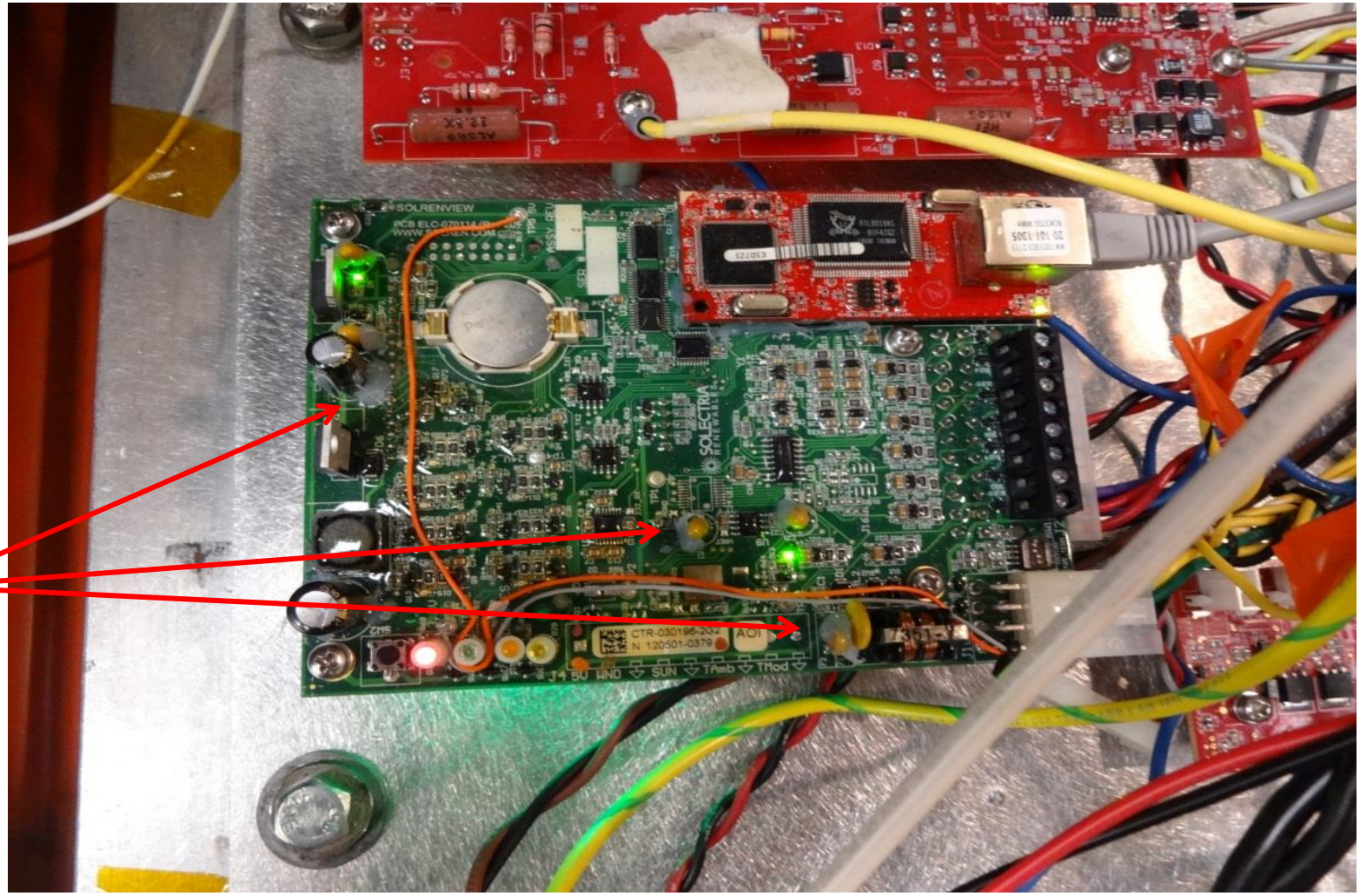
Test of ruggedized components with RTV



ALT at Solectria

Increase ambient temperature

Block air intake to reduce air-flow

Solectria ALT (Accelerated Life Testing) set up:

1) Limit air-cooling by blocking intake, power stages should be on the edge of going into derating mode.

2) Adjust intake air temp and blocking to achieve 70C cabinet temp and 80C inside power stage enclosure (DMGI enclosure)

3) Operate at maximum voltage and power level.

4) Run <u>continuous</u> cycles with the following power levels. 100% power for 11 hrs and 5% power for 1 hr, this will thermal cycle the power stages and all components inside the cabinet

Calculating Acceleration Factor

Comparative form of Arrhenius Equation

$$\text{Acceleration Factor} = e^{**}\left[(E_a / k) (1/T_1 - 1/T_2)\right]$$

where T1 is the reference temperature (e.g. 25°C / 298.15°K)
and T2 is the actual use temperature.

e	= 2.718281
E_a	is the "Activation Energy" for the physical process(es) that lead to wearout, in eV
k	is Boltzmann's Constant, 8.617×10^{-5} eV / K
T	is Temperature in degrees Kelvin (Celsius degrees plus 273.15)
eV	means "Electron Volt"

Most component manufacturers recommend using an Activation Energy (E_a) between 0.7 and 1 eV

	MIL-HDBK-217F notice 1	MIL-HDBK-217F notice 2	MIL 217 plus
Update year	1995	1996	2007
Bipolar logic	0,4 eV	0,4 eV	0,8 eV
CMOS logic	0,35 eV	0,35 eV	0,8 eV
BiCmos logic	0,5 eV	0,5 eV	0,8 eV
Linear	0,65 eV	0,65 eV	0,8 eV
Memories	0,6 eV	0,6 eV	0,8 eV
VHSIC	0,4 eV	0,4 eV	0,8 eV

Acceleration Factor for Cabinet Components

The “Typical/Average” cabinet temp in the field is 40C

Block air-flow to achieve a cabinet temp of 70C

Activation Energy (E_a) = 0.8eV

Acceleration Factor = e **[(E_a / k) (1/T_1 - 1/T_2)]

	T1 (°C)	T1 (°C)	Ea (eV)	T1 (°K)	T2 (°K)
Enter values	40	70	0.8	313.15	343.15
				Ae/k	9283.97
Acceleration Factor =		13		1/T1 - 1/T	2.79E-04
					2.592

How long do we need to run ALT to equal 20 years?

A typical inverter operates 14 hrs a day for 20 years

Total hrs = 14hrs/day x 365 days x 20yrs = 102,200 hrs

102,200 hrs / Acceleration Factor AF = 13

102,200 hrs/13 = 7862 hrs

Since we are running ALT for 11 hrs @100% power and 1 hr @5% power that's 22 hrs/day running at Full Power.

7862 hrs ÷ 22 hrs/day = 357 days or about 12 months

Questions?